# EarthScope Existing Station Summary

Prepared by the CSP Core Team

Over the last four decades, the National Science Foundation (NSF) has sponsored facility-based instrumentation to support a growing portfolio of science from the geodesy and seismology research communities. These facilities evolved steadily during their operation by IRIS and UNAVCO with the current iterations, the Geodetic Facility for the Advancement of Geoscience (GAGE) and the Seismological Facility for the Advancement of Geoscience (SAGE), funded through September 2025. Instrumentation under GAGE and SAGE regularly operate as both temporary and permanent installations by trained Principal Investigators or highly specialized facility staff in nearly every terrestrial environment on Earth. These diverse requirements, driven by both scientific and logistical considerations, have resulted in many innovations and unique design characteristics.

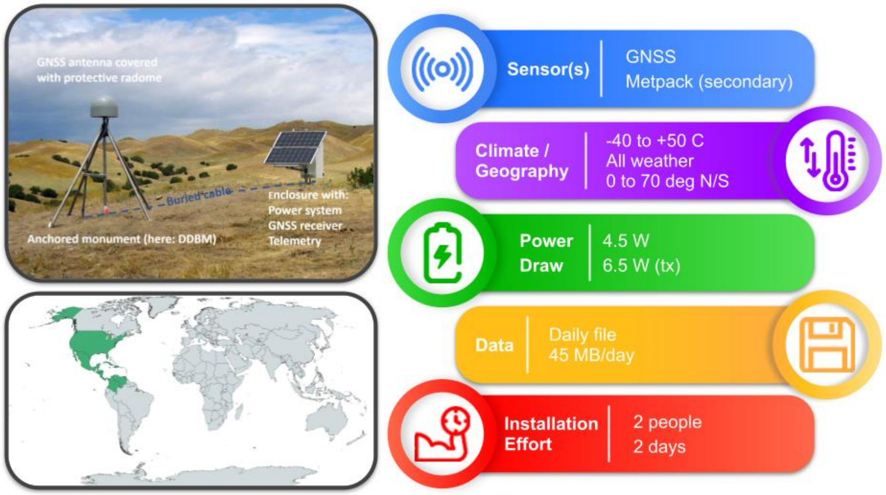
Under the EarthScope Consortium's merged management of GAGE and SAGE, the Common Sensor Platform (CSP) project provides a timely opportunity to review and evaluate development that has gone into the current design of a station type, in some cases decades of such development. In doing so, we hope to understand where potential efficiencies and commonalities can be identified in station subsystem components, design practices, deployment operations, etc. across the portfolio of stations operated under GAGE and SAGE, leading to future implementations that are more scalable and modular. With this in mind, the CSP core team developed a uniform process for capturing and reviewing this information. In the following sections, we summarize the key takeaways from the initial review of the design and operations of 10 station designs used across the present-day GAGE and SAGE networks and instrument pools.

The infographics and adjoining descriptions are intended to uniformly account for the constraints these stations operate under, and the time and human effort needed to build the site. A more nebulous factor is the preparation process leading up to work onsite which can vary widely. For an individual station this can take days to weeks of extra work, and for networks logistical planning and preparation can extend to months or even years. This may relate to specific instrumentation, but ties also to factors such as geography, climate, and accessibility of the site.

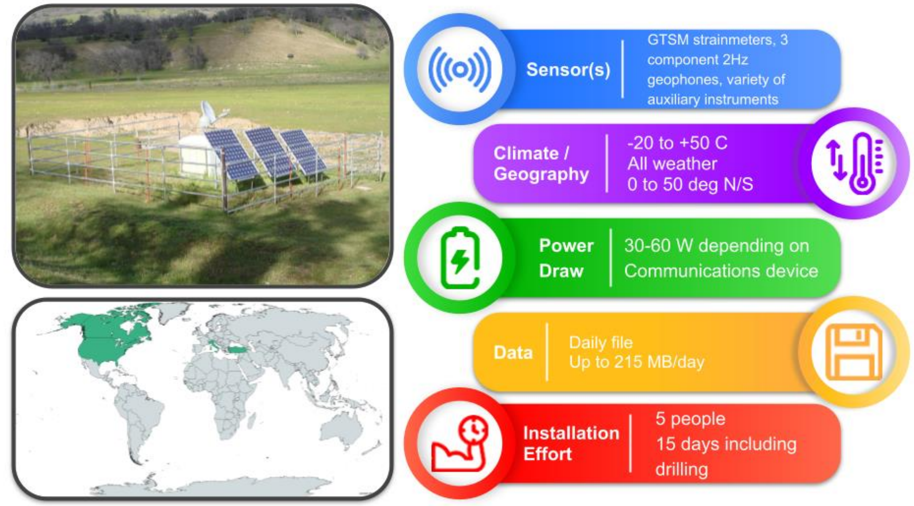
The station designs presented here are as follows:

- GAGE Network of the Americas (NOTA)
- GAGE NOTA Borehole Strainmeter
- GAGE Principal Investigator
- GAGE Polar
- GAGE Global GNSS Network
- SAGE Global Seismographic Network
- SAGE Polar Principal Investigator
- SAGE Polar Erebus
- SAGE Portable Principal Investigator
- SAGE Alaska Transportable Array

## GAGE Network of the Americas (NOTA)



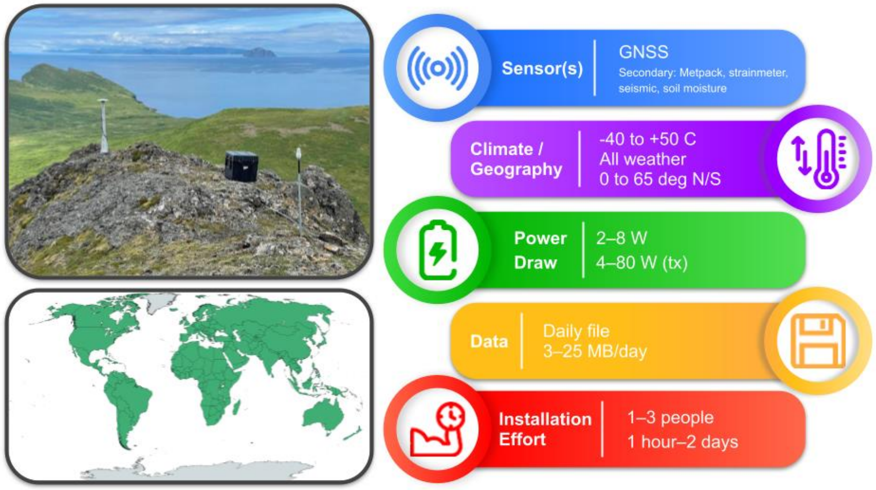

## GAGE NOTA Borehole Strainmeter




NOTA is a network of over 1100 continuously operating GNSS stations from Alaska through northern South America. It was formed from the merging of the former PBO, COCONet, and TLALOCNet networks into a single, unified network. This network is highly standardized. For the majority of stations, all components are centrally designed and tested. There are two primary monument choices, based on soil/bedrock conditions (Deep Drilled Braced Monument-DDBM or Short Drilled Braced Monument-SDBM), and two infrastructure designs (temperate or Alaska/high latitude). Some sites may be further modified or customized due to additional environmental or power requirements. A sall number of sites are non-standard, typically in cases where they were inherited from older projects or networks. Due to funding constraints, upgrades of components have been performed on an incremental basis as resources allow. NOTA has potential for further modernization and standardization of designs, including GNSS receivers and real-time telemetry options.

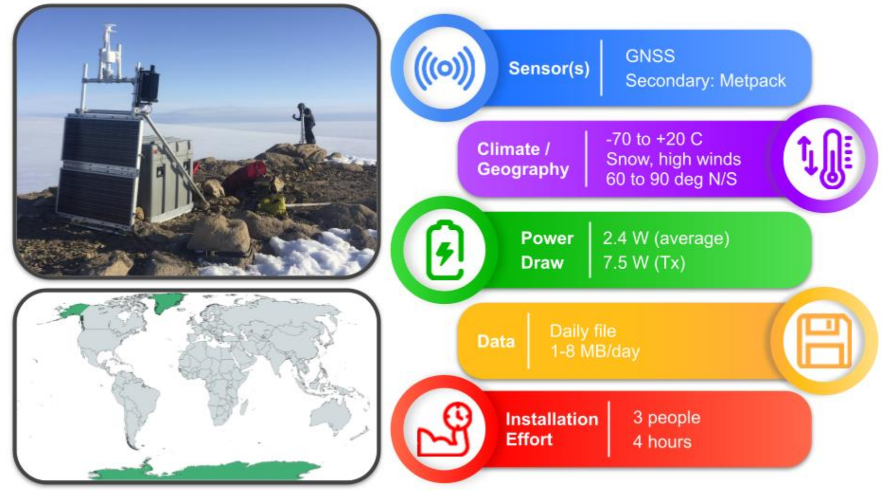
GAGE borehole strainmeter stations were initially designed to complement the PBO (now NOTA) network but have also been implemented outside of the Americas. These deeply sited borehole GTSM strainmeters have considerable installation requirements that include professional drilling and well-logging. In addition, these stations can support a wide array of other instruments, including GNSS, metpacks, tiltmeters, microbarometers, strong motion, and pore pressure. The aging of key electronics within the specialized GTSM and other core station equipment are driving ongoing technical renewal through the consideration of new communications, station computing, and operations software.

## GAGE Principal Investigators (PI)



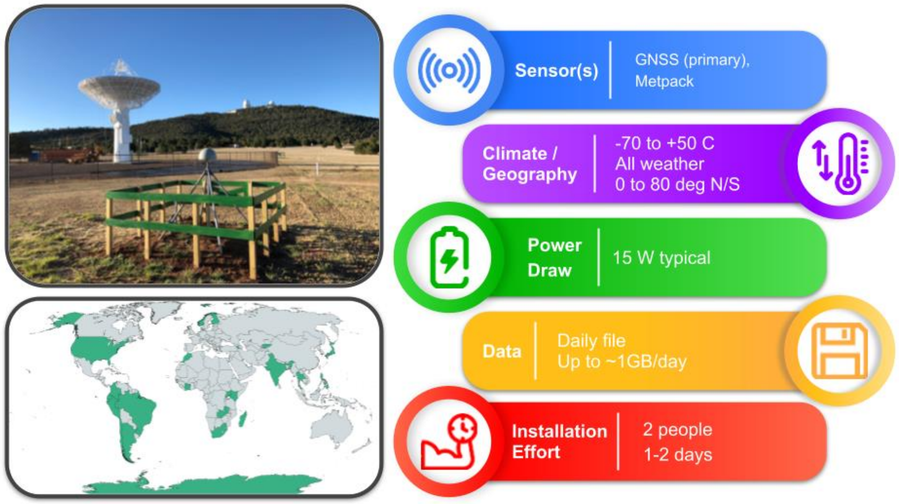

GNSS stations for GAGE Principal Investigators are configured to be suitable for deployment in a wide range of terrestrial settings based on project-specific requirements. These stations often have smaller footprints and a lower installation cost, but, based on project requirements, may be identical to NOTA Short Drilled and Deep Drilled Braced Monuments (SDBM/DDBM). Implementation leverages developments from other GAGE station topologies (NOTA-enclosures, power components, Polar-masts) to ensure that these stations are robustly designed to operate well for the duration of the project, from temporary to permanent. Reliable telemetry is typically desired for most PI sites, but it is not uncommon for some of these sites to forgo telemetry and, instead, schedule manual download visits to save on both power and equipment costs.

## GAGE Polar



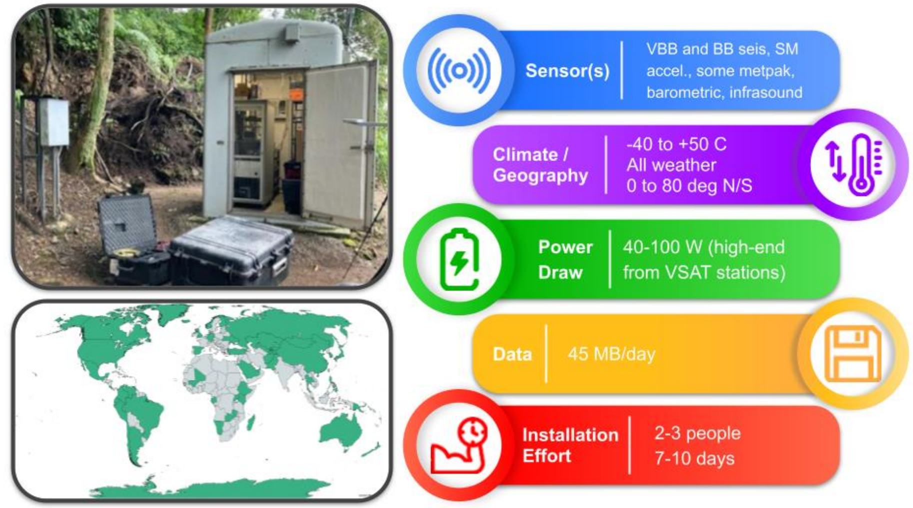

The GAGE polar permanent stations operate as multi-year deployments throughout Greenland and Antarctica, mostly under the umbrella of the GNET and ANET networks. The stations are designed to be installed on bedrock and operate autonomously for durations of a year or longer, providing telemetered data and state-of-health monitoring via Iridium modem communications. The current implementation of these stations is the product of a 15-year evolutionary path in design that sawchanges to various subsystems during their operation. One recent design efficiency that streamlines onsite logistics is a collapsible frame on which to mount solar panels, antennas, and auxiliary instruments. To guarantee overwinter functionality, these stations require significant power storage and thus require a considerable amount of batteries. In addition to the GNET and ANET networks, a small number of stations also operate as standalone reference stations for numerous PI projects in northern Alaska.

## GAGE Global GNSS Network (GGN)



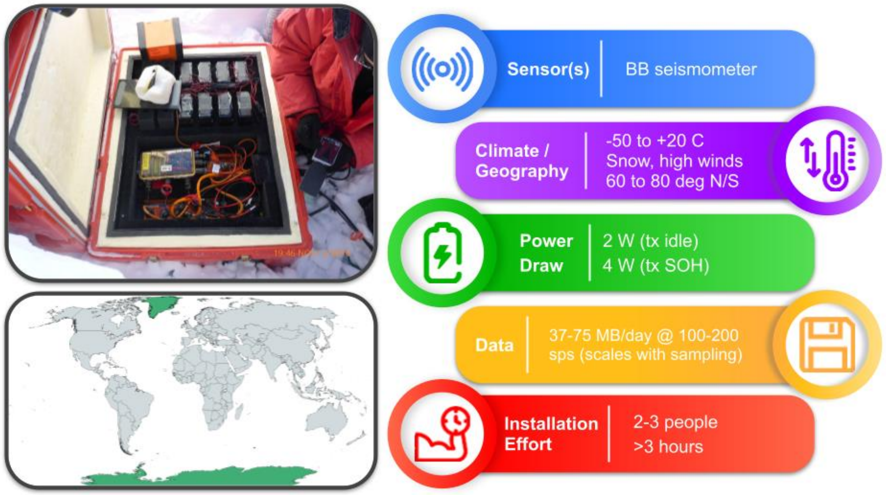

Under the direction of, and in partnership with, Jet Propulsion Laboratory (JPL), EarthScope manages the operations and maintenance of the NASA Global GNSS Network (GGN) which comprises roughly 63 globally distributed continuous reference stations. It is one of the longest operating networks in the world with time series extending 30+ years from some of the oldest stations. A typical station is located at a collaborating university or government organization which provides local technical support, power, and networking infrastructure. Standards have evolved over the years, resulting in some diversity in antenna monumentation. The majority of the stations are members of the International Ground Station (IGS) network and, therefore, strict quality reliability standards must be maintained through regular hardware and firmware upgrades, and troubleshooting issues with the aid of local support. Data from these stations contribute to defining the International Terrestrial Reference Frame (ITRF), satellite orbit clock corrections, atmospheric data products, and numerous other scientific applications.

## SAGE Global Seismographic Network (GSN)



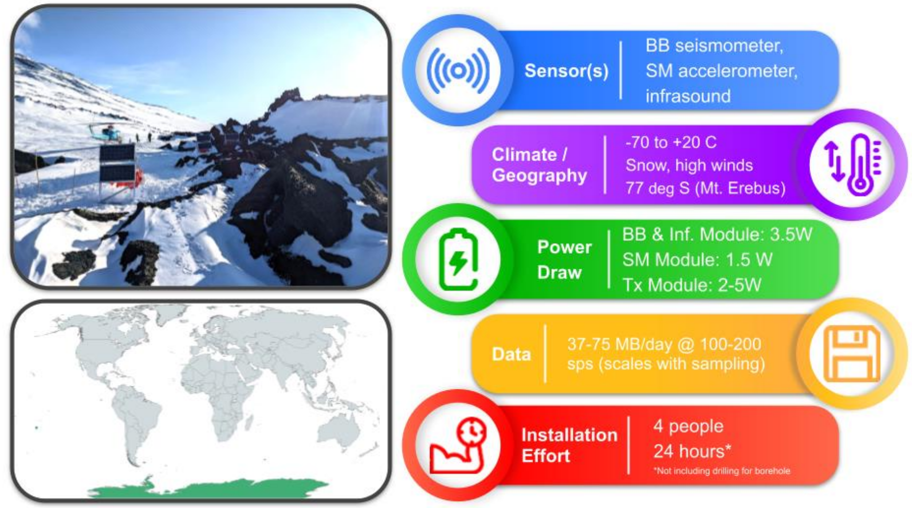

The Global Seismographic Network is a network of very broadband seismometers deployed to achieve worldwide coverage as uniformly as possible. It is jointly operated by the SAGE facility (EarthScope and UC-San Diego) and the USGS Albuquerque Seismological Laboratory. The design of the GSN is heterogeneous, with a long history of site selection and station operation. The network is focused on obtaining a global distribution of very quiet long period seismographic signals, and thus operates in a variety of remote and unique terrestrial environments. Most stations are either vault or deep borehole and feature unique designs based on site requirements and need for autonomous operation. EarthScope and the USGS work closely to manage the GSN and take advisory input from the community of global end-users. Technological advances to communications, station computing, and instrumentation are driving the network's modernization. GSN stations contribute to global monitoring of earthquakes and tsunamis by the USGS and NOAA, as well as helping to enforce the Comprehensive Test Ban Treaty.

## SAGE Polar PI Stations



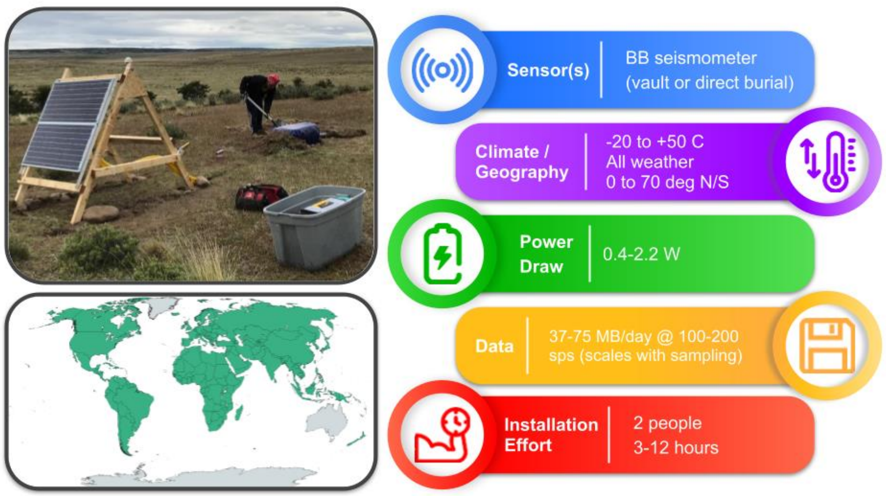

This SAGE station design for 1-3 year telemetered Polar seismic stations was developed and refined using feedback from several PI projects in Antarctica. The insulated enclosure facilitates a plug-and-play approach with distinct slots for modular, swappable subcomponents, minimizing the potential for errors during installation and maintenance. It is a lightweight system, relying on a bank of incredibly energy dense, non-rechargeable lithium batteries for winter power and a small, rechargeable lead acid battery for summer power. These stations can support telemetry of state-of-health metrics and/or near real-time telemetry of seismic data up to 20 sps. This design has been successfully used for nearly a decade, but the rise of next-generation electronics is driving the need for an upgrade.

## SAGE Polar Erebus



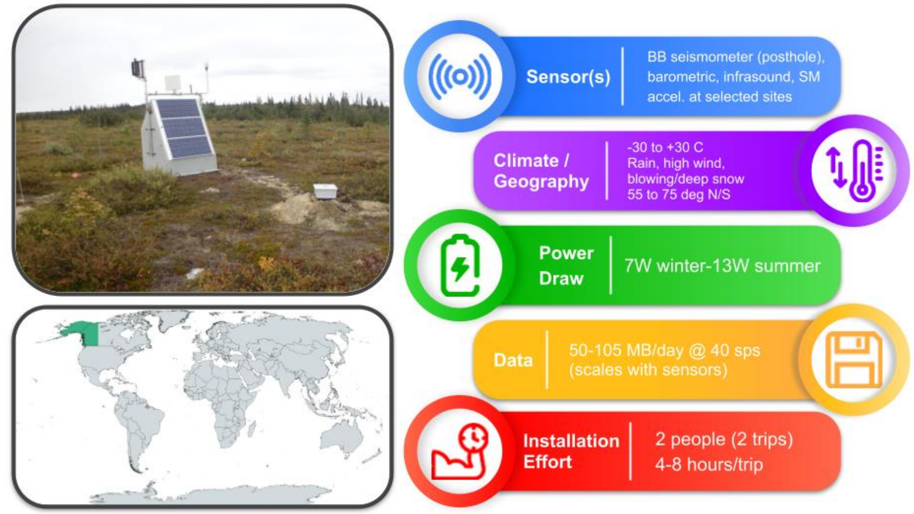

Mt. Erebus is the southernmost active volcano in the world, located on Ross Island in Antarctica. Because it has been in a continual state of activity for >50 years, it is of notable scientific interest. The Erebus Backbone Network (EBN) is a mixed-modal sensing network consisting of broadband seismic, infrasound, and accelerometer instrumentation that has been designed to collect data for further investigation into the volcano's physical processes. The EBN's modular station design is in the initial deployment phase, pending final upgrades of a subset of stations and planning for the long-term emplacement of borehole seismometers. This modular design uses individual enclosures for instrumentation subsystems, which requires a long lead time for fabrication. Initial stations have been successfully deployed and provide near real-time telemetry of state-of-health metrics, as well as 20 sps broadband seismic data.

## SAGE Portable Principal Investigator




Portable stations for SAGE PI seismic deployments involve a core group of vault or direct burial seismometers and digitizers along with charge controllers to regulate power systems with batteries and solar panels. The exact configuration of these stations in the field depends on both the PI, who chooses the consumables used for building the station, and the requirements of the experiment, which can vary enormously. Typical deployments last ~2 years, and have occurred in a wide range of terrestrial environments worldwide. Most deployed stations are not telemetered and data is collected only on service visits or when the site is demobilized. Quick deploy boxes have been developed for RAPID response projects, and these provide a more integrated station design in a single unit for this particular usage case.

## SAGE Alaska Transportable Array




Transportable Array stations operated in Alaska and northwest Canada in long-term emplacements officially from 2011-2021, but many have been adopted as permanent stations. These stations were designed to operate indefinitely across highly variable environments with potential limited logistical support for frequent or extended visits. These TA stations used BB seismometers installed in specialized postholes drilled with a downhill hammer drill (or auger) and were equipped and powered to transmit real-time data and state-of-health overwinter. Many stations also included environmental sensors (metpacks, microbarographs, and infrasound sensors) along with strong motion sensors to enhance the environment and hazard monitoring capabilities within the array.